Title: Status of the Large Millimeter Telescope (LMT) and EHT Preparations

Date: Nov 13, 2014 12:00 PM

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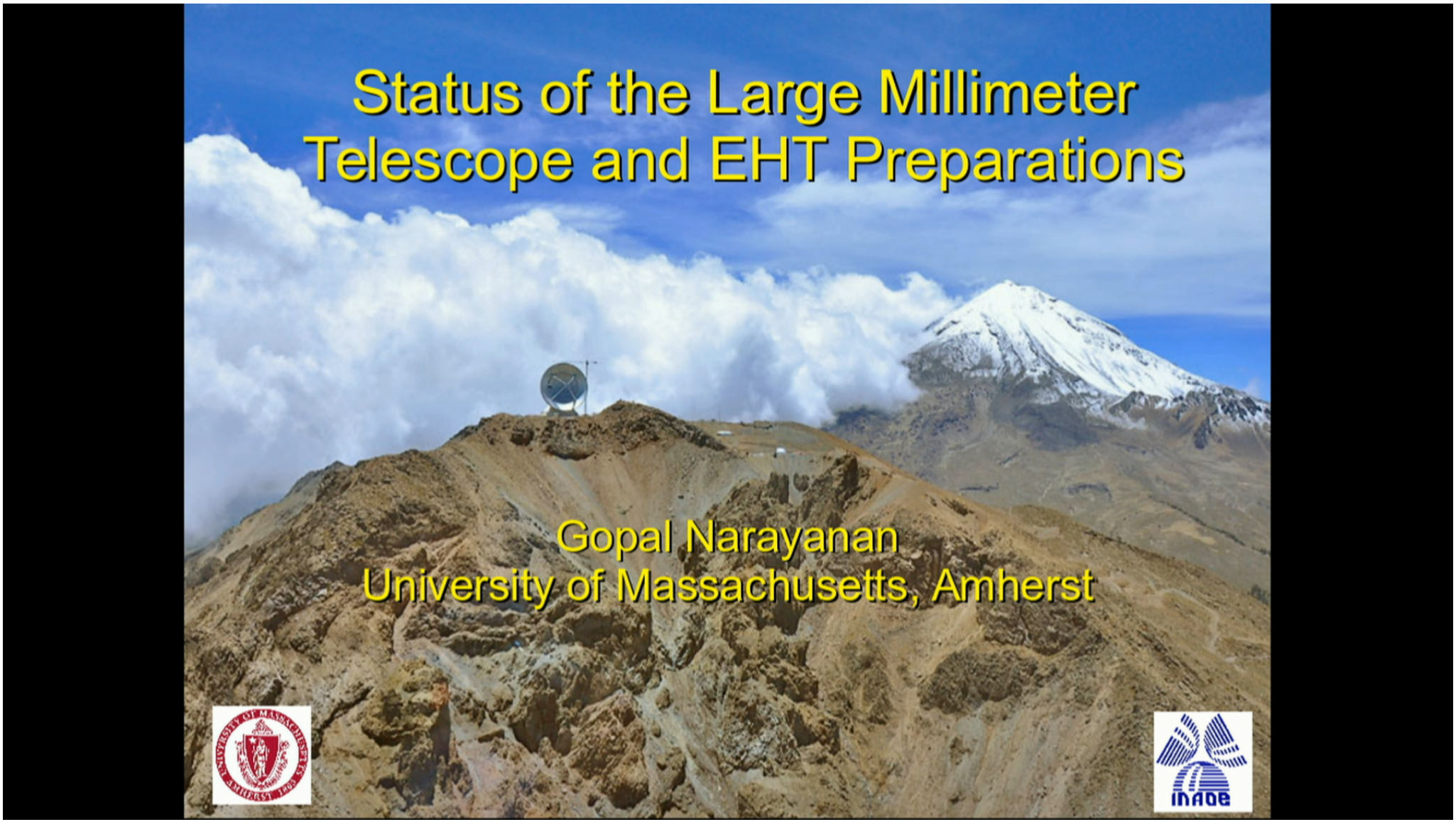
Abstract: The Large Millimeter Telescope (LMT) is a 50m diameter telescope at an altitude of 4600 m in the country of Mexico. It is a joint project between the University of Massachusetts, Amherst and the Instituto Nacional de Astrofisica, Optica y Electronica (INAOE). At this time, the inner three rings of the telescope have been furnished with precision surface panels for an effective diameter of 32.5 m and effective surface rms better than 80 microns. With an active primary surface, the LMT can maintain this surface over a wide elevation range. While the outer rings will be procured and installed in the next 2 years, the telescope is into its third year of early science with two receivers, the Redshift Search Receiver (RSR) and AzTEC. I will provide a short description of the engineering and scientific status of the LMT. I will also summarize VLBI activities at the LMT to date, and present plans for a dual-polarization 1mm wavelength receiver for the LMT that will enable the telescope to participate in the EHT experiment by 2016.


Status of the Large Millimeter Telescope and EHT Preparations
Gopal Narayanan
University of Massachusetts, Amherst
INAOE


Pico de Orizaba (Citlaltépetl)
5740 m; 18832 ft
LMT / Sierra Negra (Tliltépetl)
4600m; 15091 ft
97° 18′ 53″ W, +18° 59′ 06″
Puebla 2200m - 120 km from INAOE/Puebla to LMT

Large List of Collaborators

- Peter Schloerb, Neal Erickson, Ron Grosslein (UMass)
- Jonathan Leon Tavarez (INAOE), Gisela Ortiz & Laurent Loinard (CryA UNAM)
- David Hughes, Arak Olmos & Site crew (LMT)
- Shep Doeleman (CfA, MIT Haystack)
- Joseph Crowley, Vincent Fish, Jason Soohoo, Alan Rogers, Mike Titus, Chris Beaudoin (MIT Haystack)
- Vivek Dhawan, Mark Claussen (NRAO VLBA)
- Dick Plambeck (CARMA)

OVERVIEW

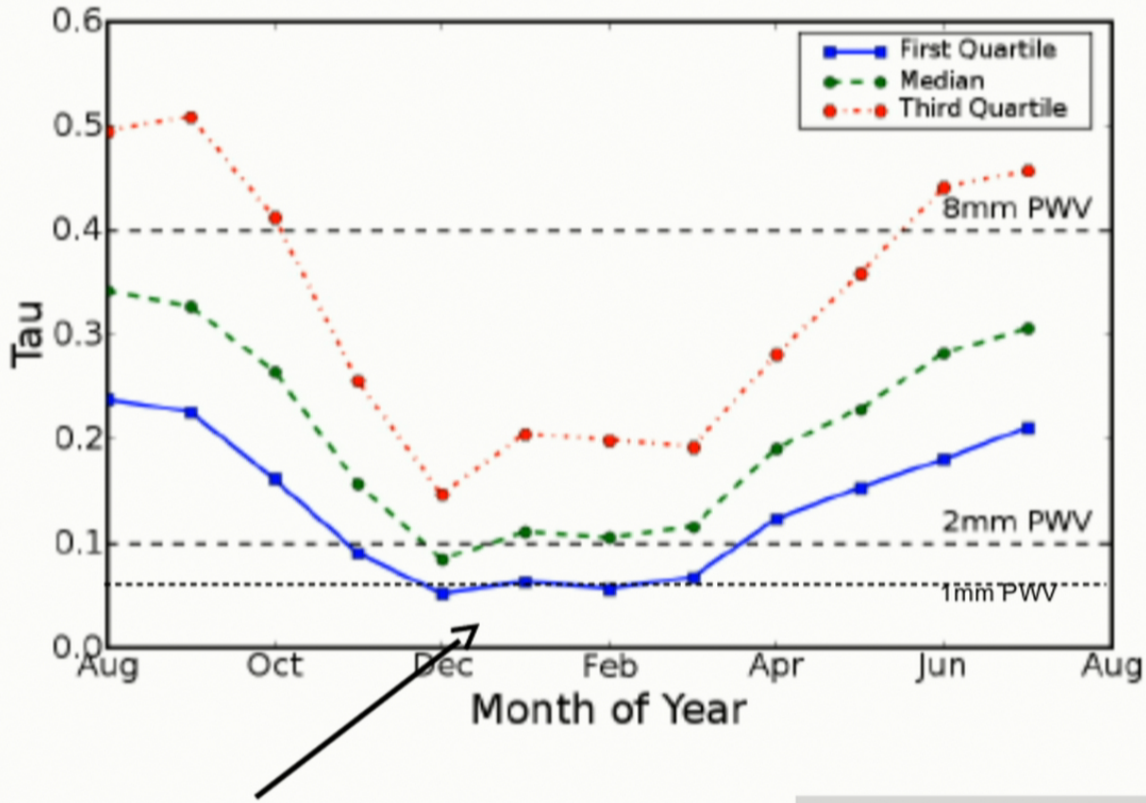
- **LMT Status**
- **Brief Outline of Scientific Results**
- **3mm VLBI Results**
- Preparation for 1mm VLBI at the LMT
  - Interim Receiver for 2015
  - Facility VLBI Receiver for 2016

About the LMT....

- 50m diameter millimeter-wave telescope
  - 75 microns RMS surface accuracy
  - 1 arcsec relative pointing
  - Active Primary Surface
  - Focal Plane Array Instrumentation

- Binational Collaboration with Mexico
  - Site in state of Puebla, MX
  - Seasonal site: Submm winter; 3mm summer.

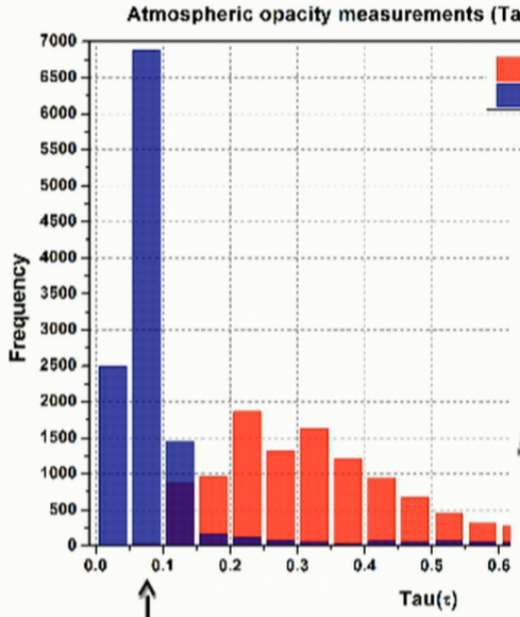
Monthy-averaged (day+night) opacity (225 GHz)

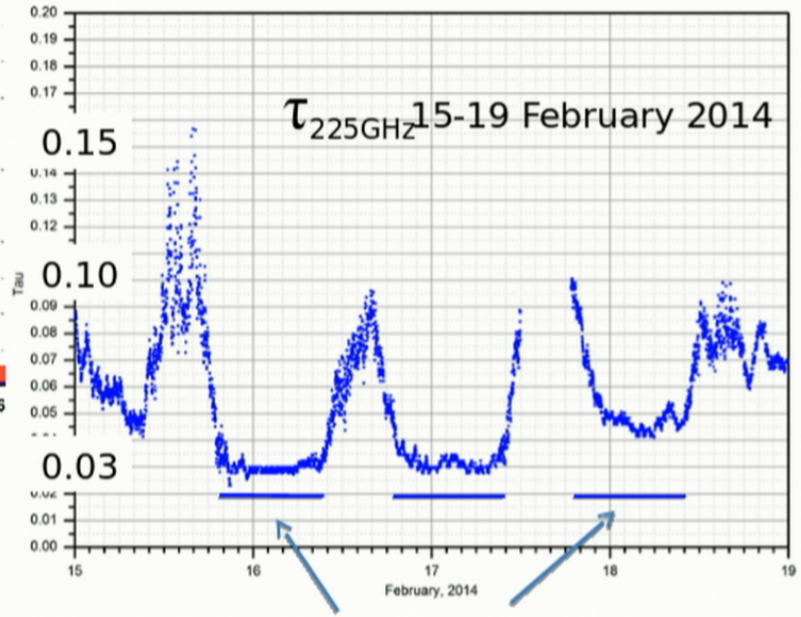


good submillimeter (345 GHz) conditions
20% time – December to March

night-time opacity
equivalent to 1st quartile

Night-time opacity (225 GHz) – summer vs. winter



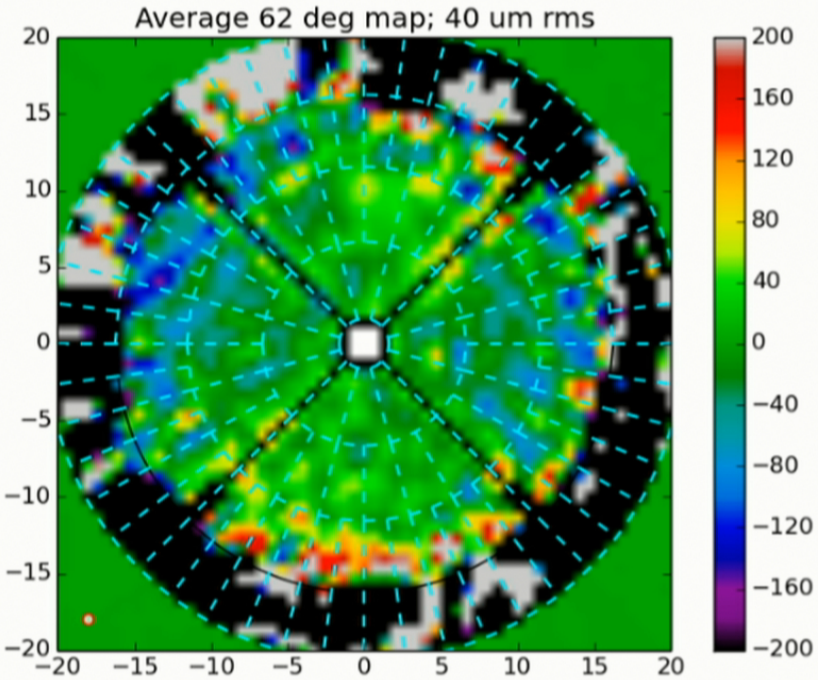


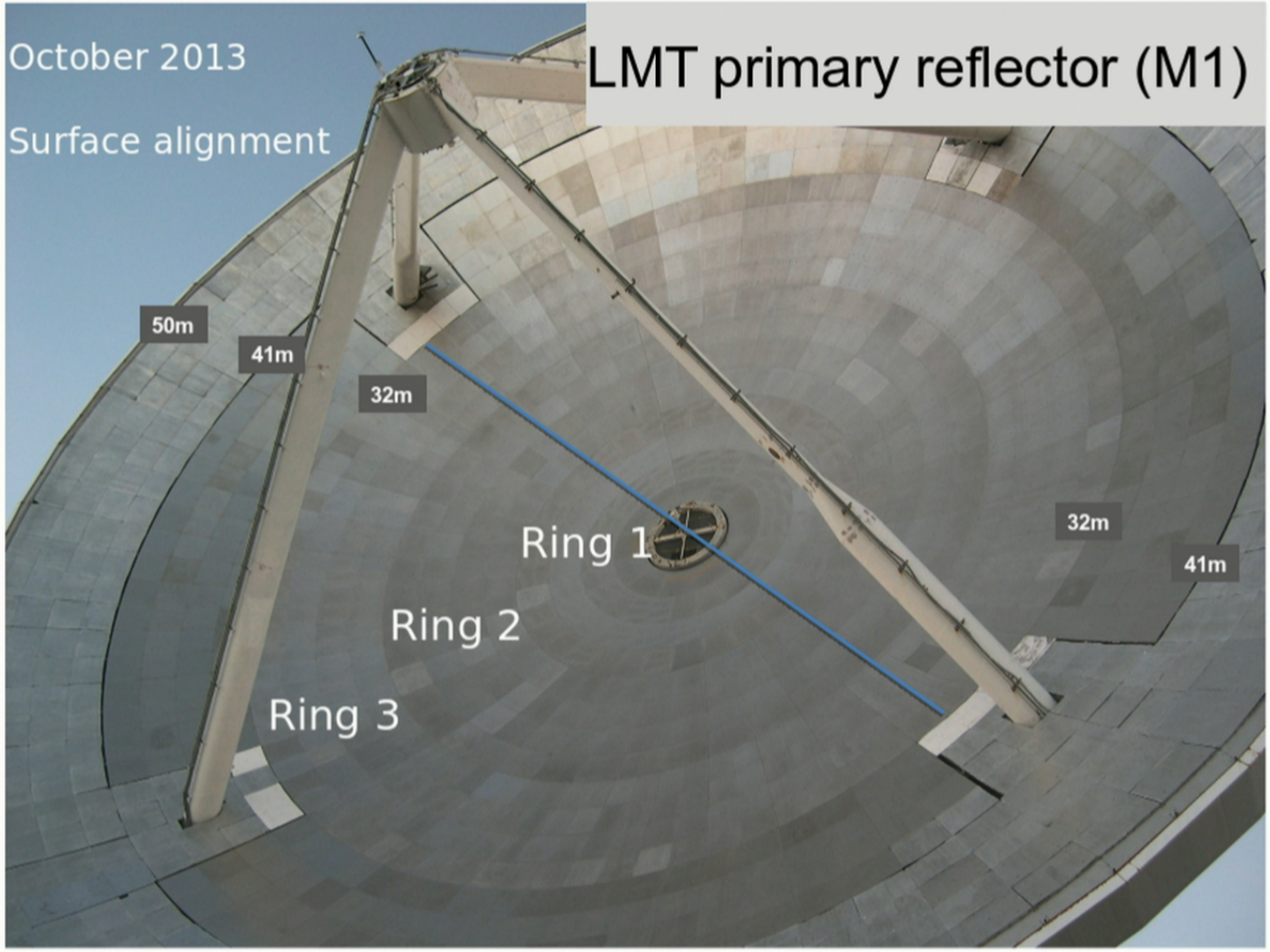
submillimeter conditions

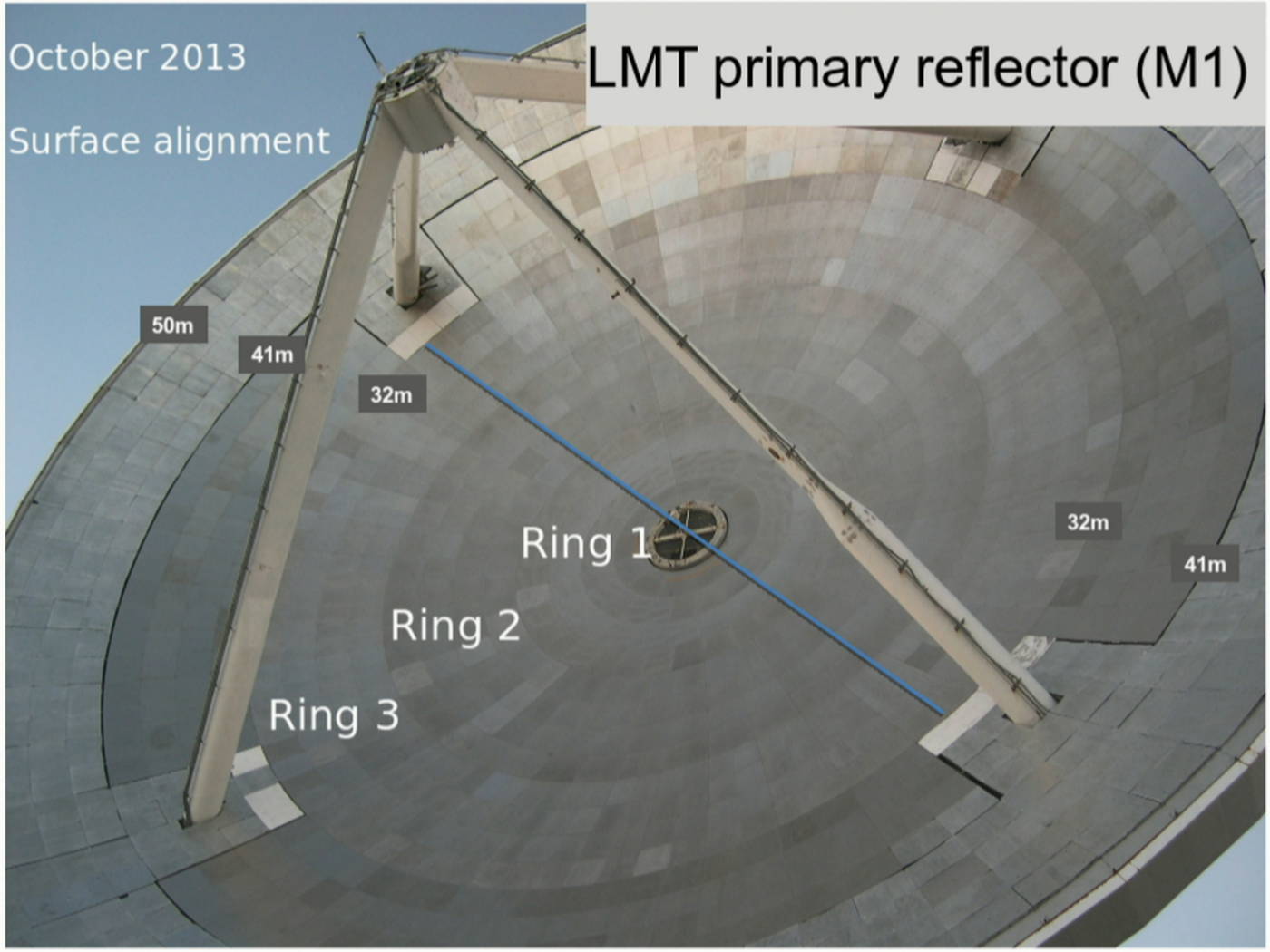
19:00 – 10:00

LMT Employs Microwave Holography to Set Surface

Use 12 GHz beacons from geo-stationary satellites to construct complex far-field map. Fourier transform to get aperture plane phase → maps to surface errors!




October 2013
Surface alignment
LMT primary reflector (M1)
50m
41m
32m
Ring 1
Ring 2
Ring 3
32m
41m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50m
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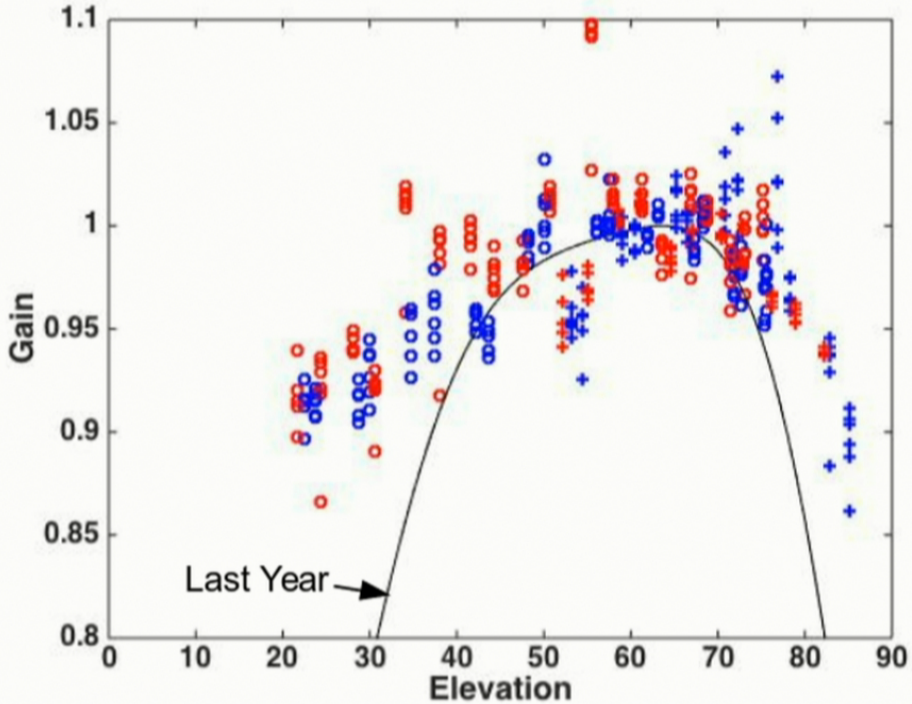
LMT Gain v. Elevation

3mm Observations of Uranus and OJ287 – Oct 30-31, 2014



Improved Active Surface model for LMT based on:

1. Greater elevation range of holography data
2. Use of OOF holography to improve some low-order surface deformations

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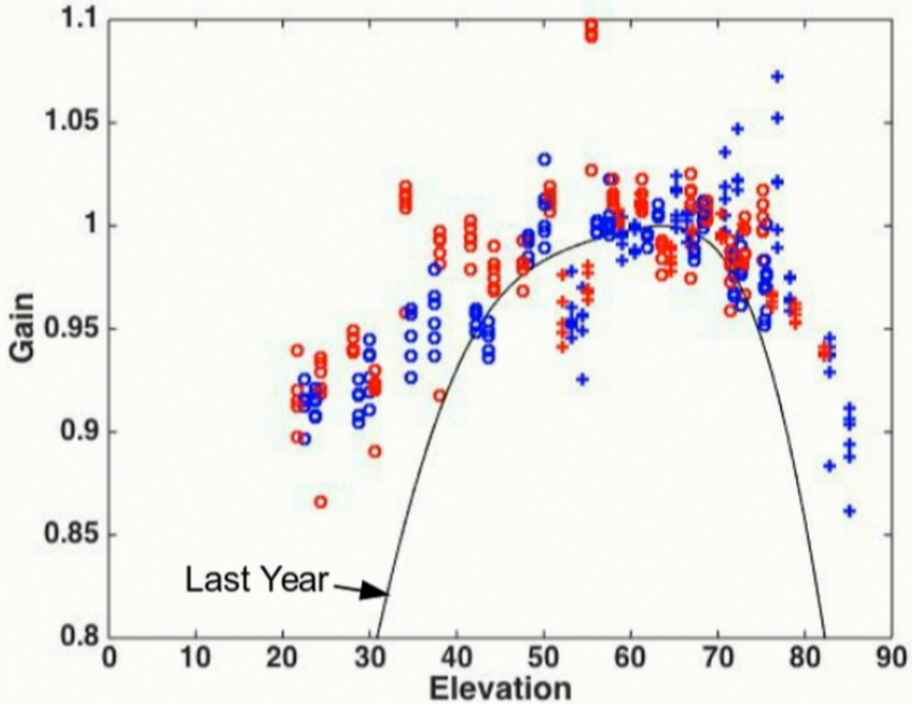

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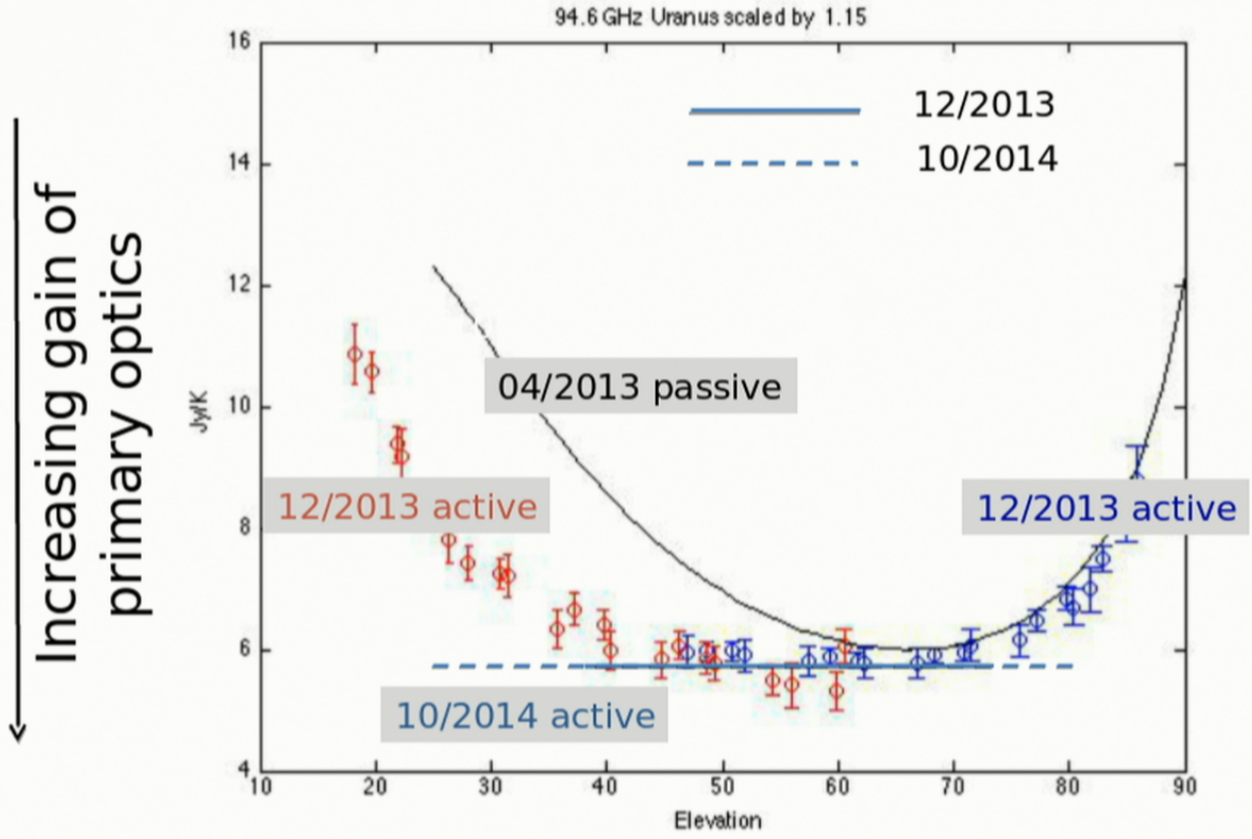
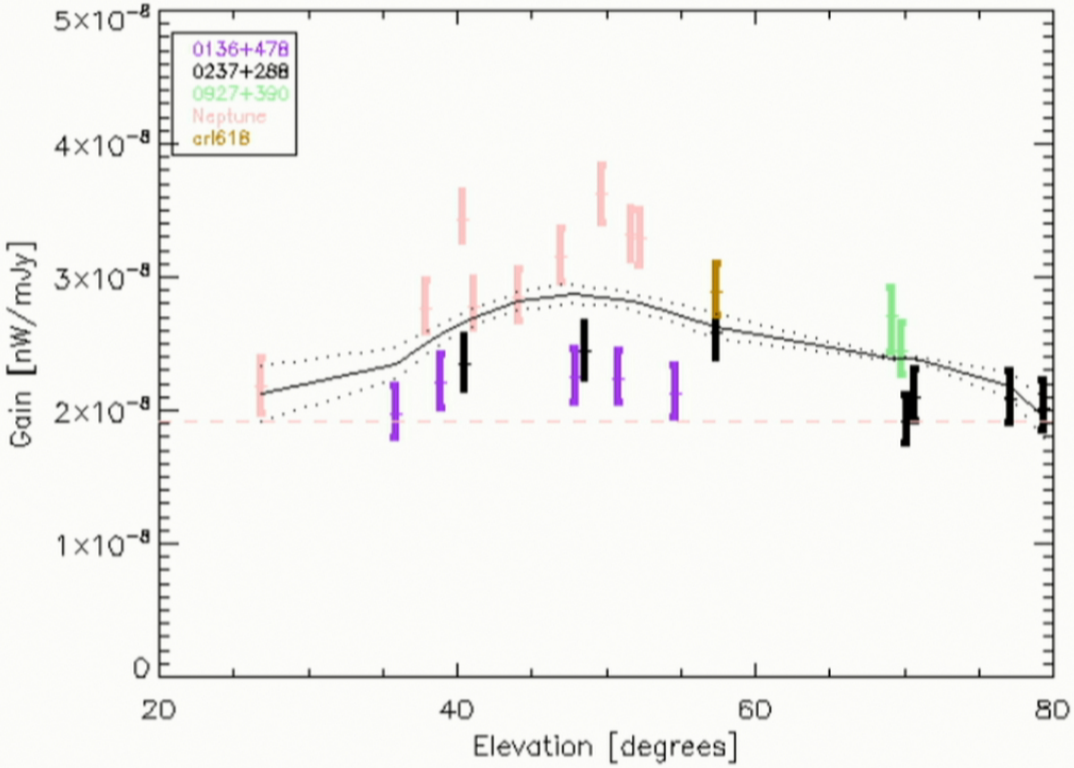
Improvement of active surface control (2013-2014)



Gain Curve at 1.1mm

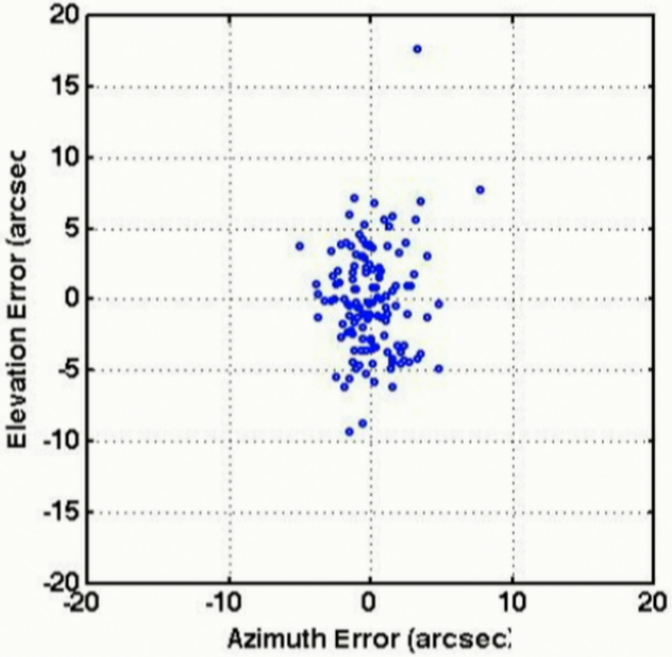


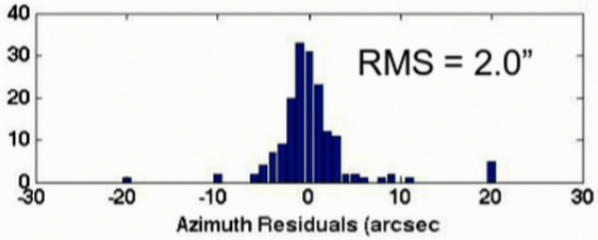
Observations of sources with the AzTEC camera

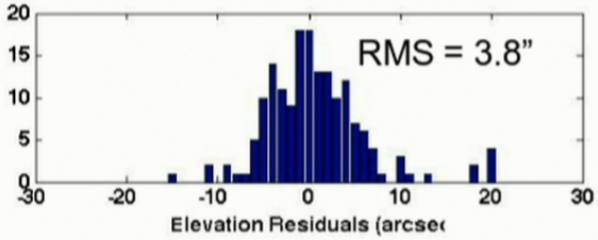
No strong gain variation at 1.1 mm

LMT Absolute Pointing

Measurements from October 2014 Pointing Run







- LMT continues to point well with stable model coefficients
- Offset pointing is usually good to 1-2”
- Elevation pointing is currently limited by a poor connection between structure and encoder

The LMT Scoreboard

Specification	Desired	Achieved (2014)
Diameter	50m	32m
Surface Accuracy Active Surface RMS (microns) Elevation Range (deg)	 Yes 75 15 – 85	 Yes 60 25 – 80
Pointing Accuracy Absolute (arcsec) Relative (arcsec)	 N/A < 1	 3 1.5

Science with the LMT

Two Instruments already in place:

- AzTEC: A 1.1 mm wavelength continuum camera
- Redshift Search Receiver (RSR) – 3mm wavelength ultra-wideband (38 GHz) spectrometer

Third season of “Early Science” Observations started early October 2014

- Future Instruments: SEQUOIA + wideband spectrometer (3mm FPA: 2015); One Millimeter Array Receiver (2018+); TolTEC (Next Gen Continuum Camera; 2016 +)
- VLBI Instruments

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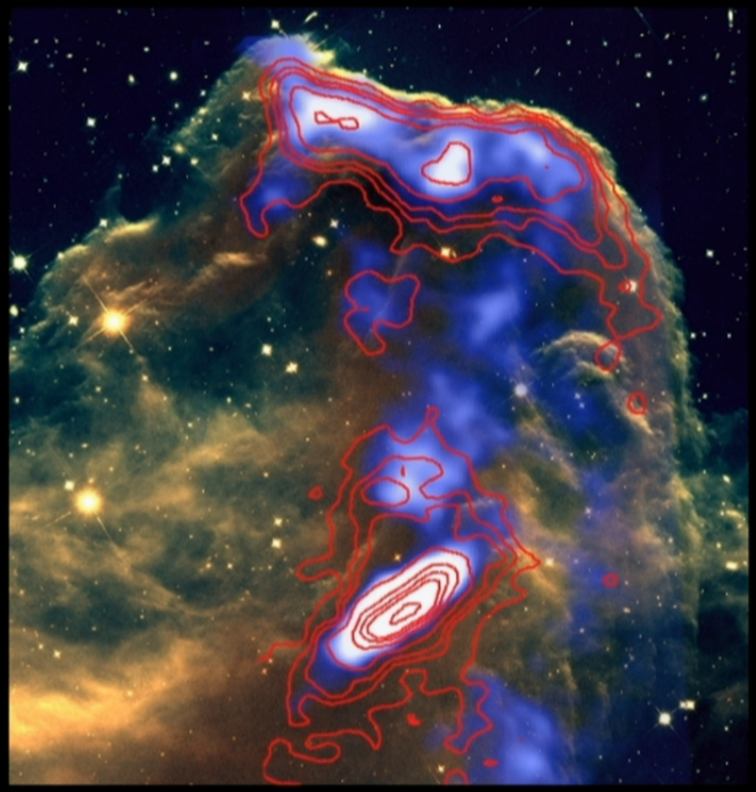
AzTEC at the LMT

- 144-pixel bolometer array
- 1.1mm Wavelength
- 8” HPBW
- Lissajou “On-the-Fly” Mapping

Horse Head Nebula

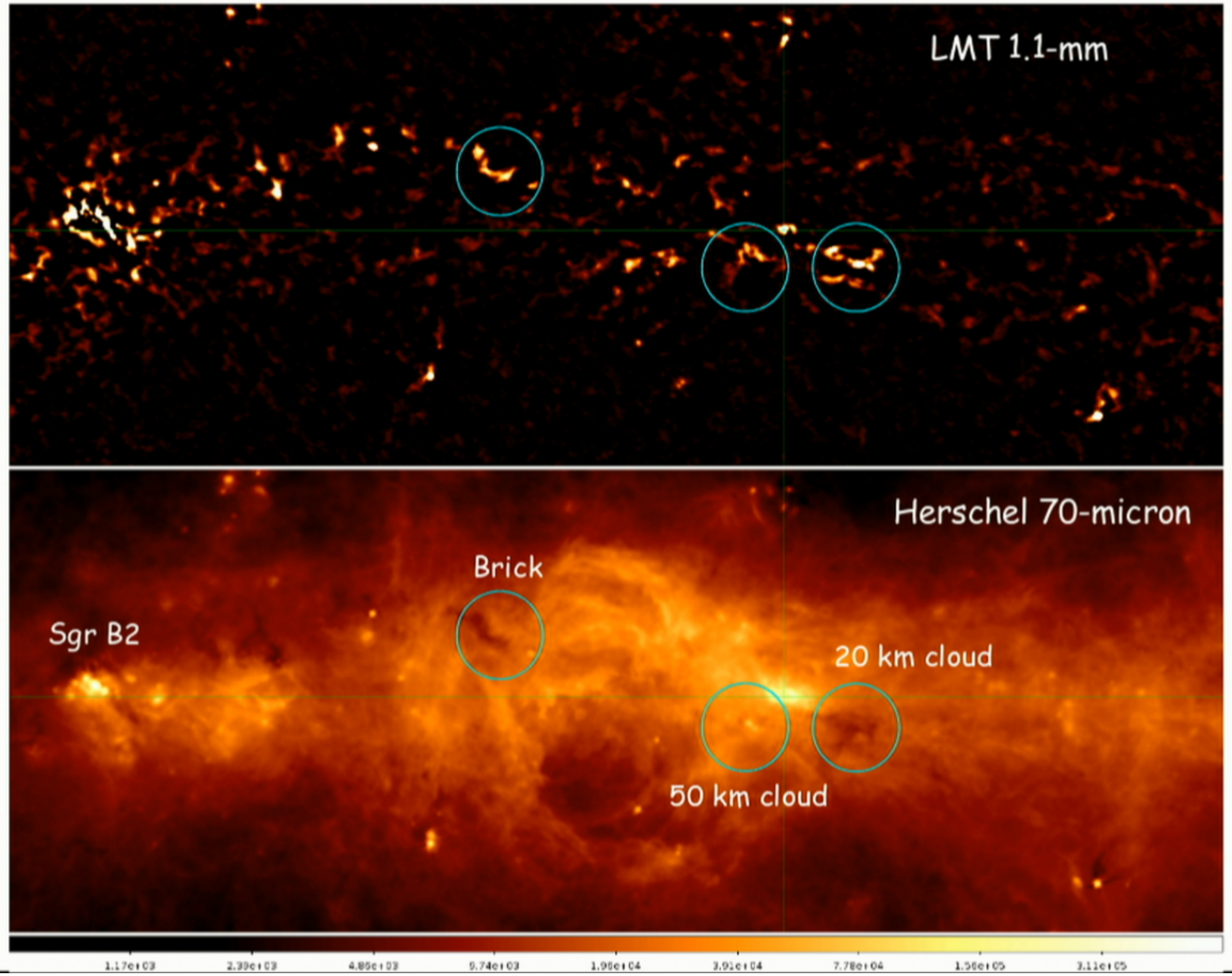


Background Image: HST WFC3 NIR F160W&F110W
Blue/White Regions: AzTEC/LMT 1.1mm
Red Contours: SCUBA 450um

Image Courtesy: D. Sanchez

AzTEC Mapping of CMZ in GC

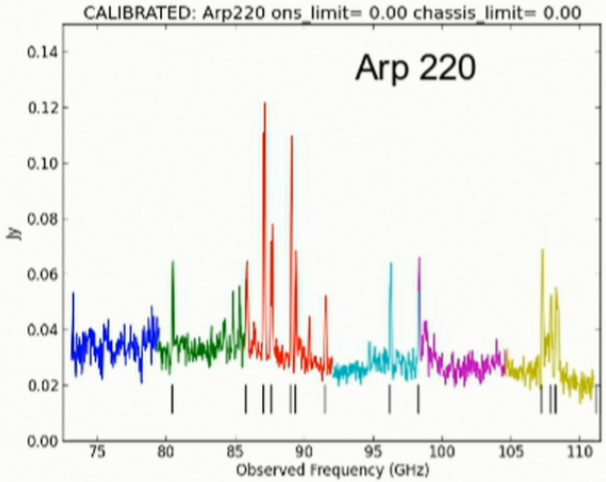
Daniel Wang



Redshift Search Receiver

- 73 – 111 GHz
  - 38 GHz Bandwidth
  - 31 MHz Resolution
- Dual Polarization, Dual Beam Receiver
- Excellent baselines
- High Sensitivity
  - Trx ~ 75K
  - Tsys ~ 100K

Erickson, Narayanan et al (2007)



One Hour Integration
No Baselines Removed

Arp 220

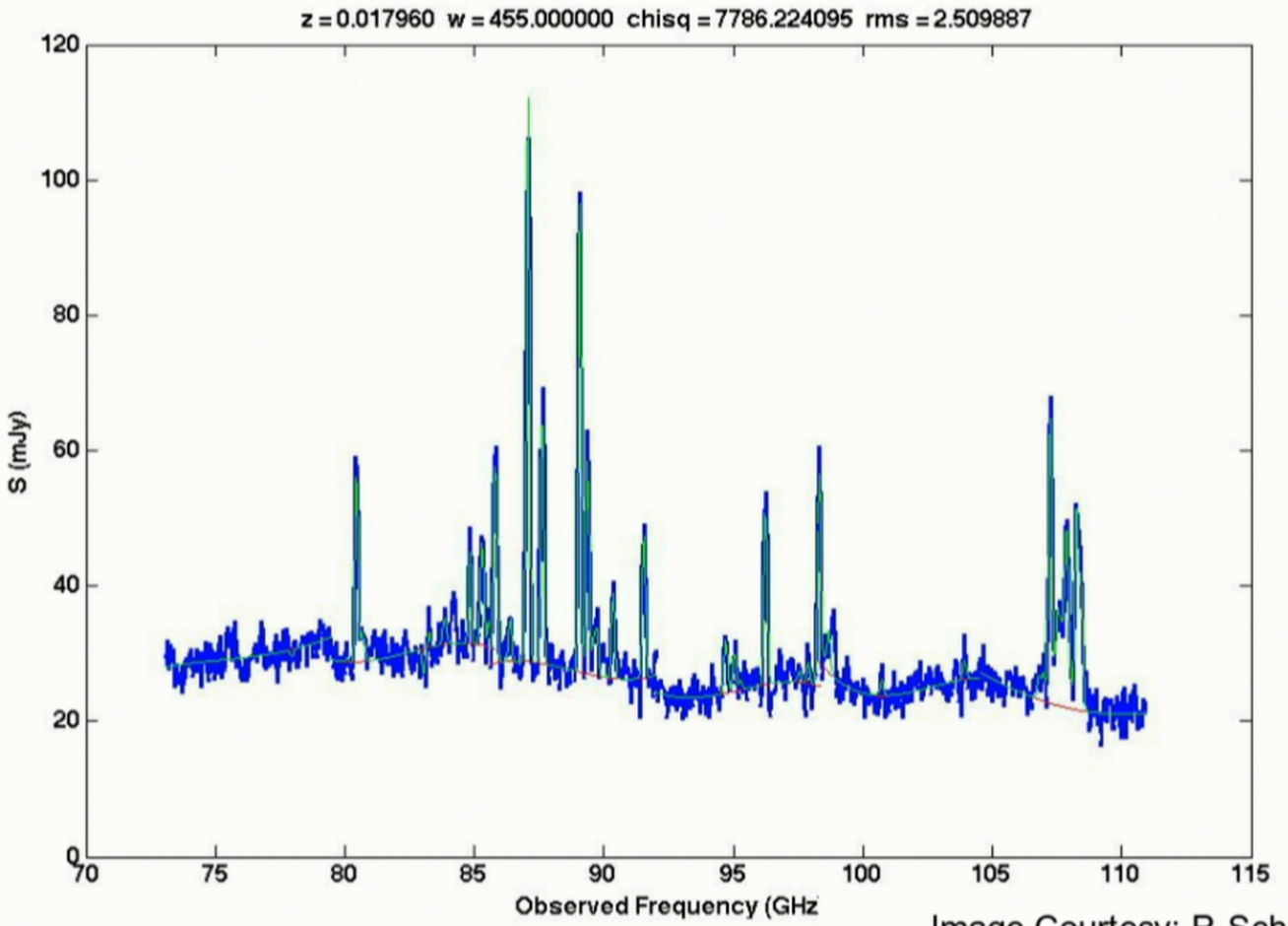


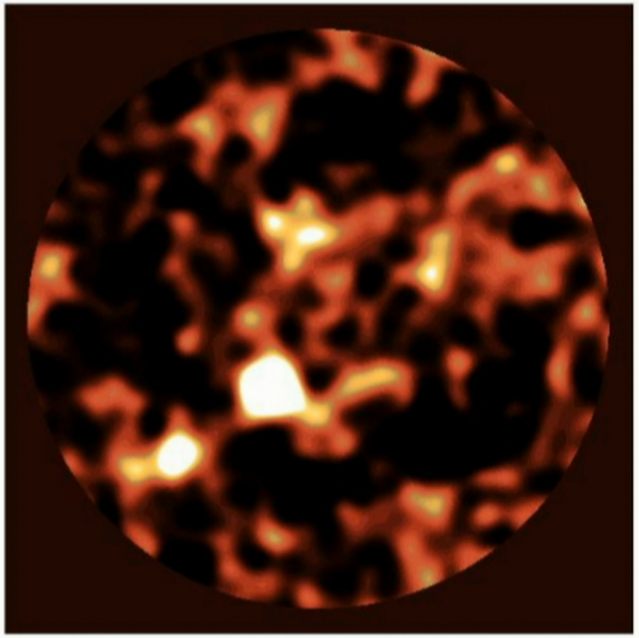
Image Courtesy: P. Schloerb

Molecular Line Detections in Arp 220

Molecule	Transition	Frequency (GHz)	Amplitude (mJy)	Error (mJy)	SNR
ch3cn	6-5	110.38	17.0	1.4	12.4
13co	1-0	110.20	29.4	1.4	21.5
hnco	5(0,5)-4(0,4)	109.91	9.4	1.5	6.3
c18o	1-0	109.78	23.9	1.5	16.1
hcccn v7	12-11	109.60	10.7	1.4	7.6
hcccn v7	12-11	109.44	13.2	1.4	9.3
hcccn	12-11	109.17	42.2	1.9	22.0
hcccn v7	11-10	100.47	6.3	1.5	4.1
hcccn v7	11-10	100.32	1.6	1.6	1.0
hcccn	11-10	100.08	28.1	1.4	20.4
cs	2-1	97.98	25.6	1.4	17.9
ch3oh	2(0,2)-1(0,1)	96.74	5.5	1.4	3.9
c34s	2-1	96.41	7.8	1.4	5.5
n2h+	1-0	93.17	21.2	1.5	14.1
ch3cn	5-4	91.98	12.8	1.5	8.6
hcccn v7	10-9	91.33	6.6	1.5	4.4
hcccn v7	10-9	91.20	4.8	1.5	3.2
hcccn	10-9	90.98	31.7	1.5	21.6
hnc	1-0	90.66	70.1	2.0	34.3
hco+	1-0	89.19	36.4	1.5	24.3
hcn	1-0	88.63	83.2	1.5	55.1
hnco	4(0,4)-3(0,3)	87.93	6.3	1.6	4.1
c2h	1-0 1/2-1/2	87.40	11.9	1.8	6.6
c2h	1-0 3/2-1/2	87.32	24.5	1.6	15.7
sio	2-1	86.85	13.8	1.8	7.7
h13co+	1-0	86.75	4.7	1.7	2.8
h13cn	1-0	86.34	13.9	1.6	9.0
hcccn v7	9-8	82.20	2.9	1.6	1.8
hcccn v7	9-8	82.08	4.2	1.6	2.7
hcccn	9-8	81.88	27.9	1.6	18.0

LMT's Killer App
Galaxy Evolution

Submm View

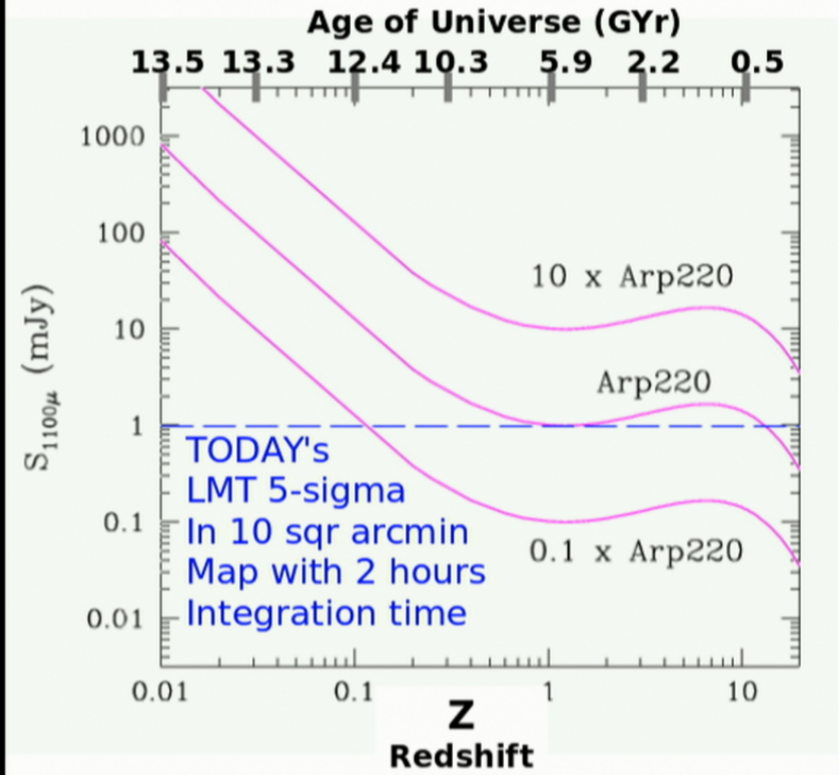


Hughes et al. 1998

Optical View

Williams et al. 1997

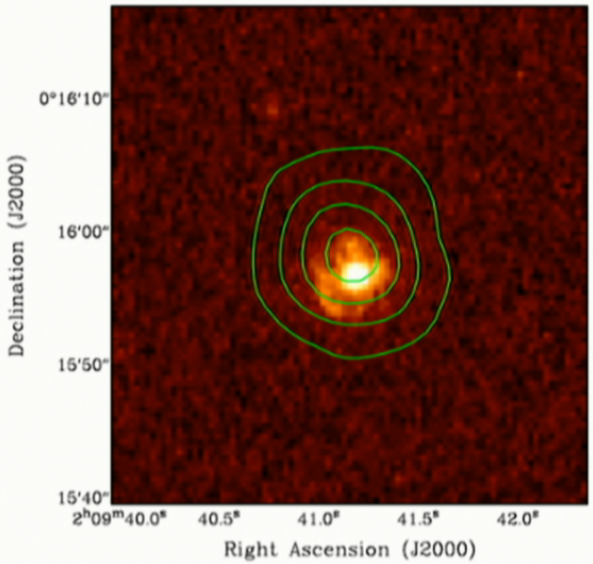
Observations of Distant Galaxies

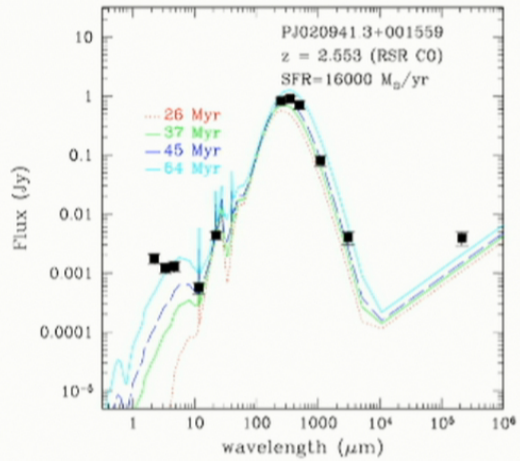


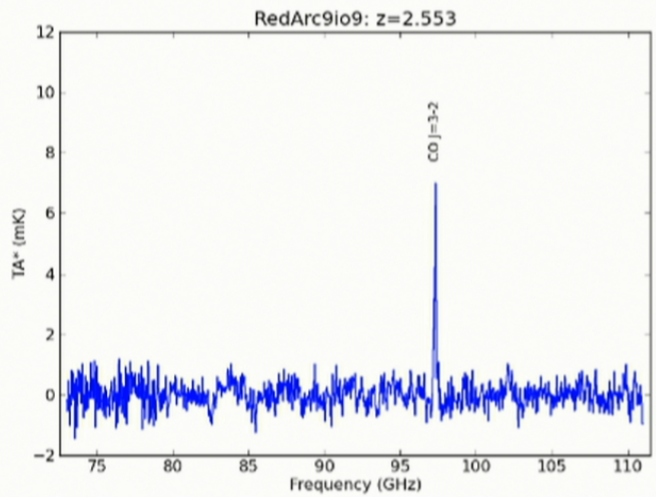
- Continuum flux from dusty starbursts is almost *independent* of redshift
- In some models and cosmologies, objects get *brighter* with *z*.

9io9 (z=2.54)

AzTEC (8")



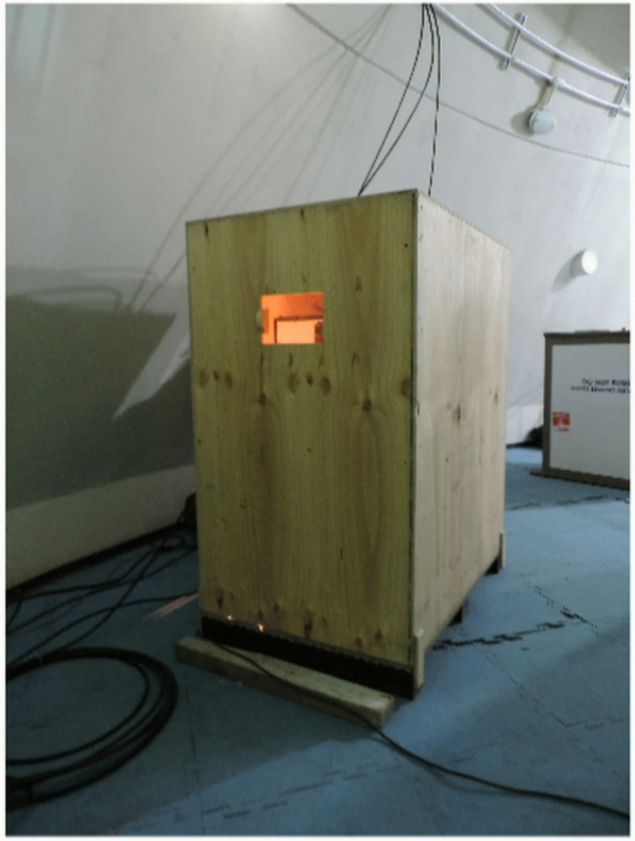




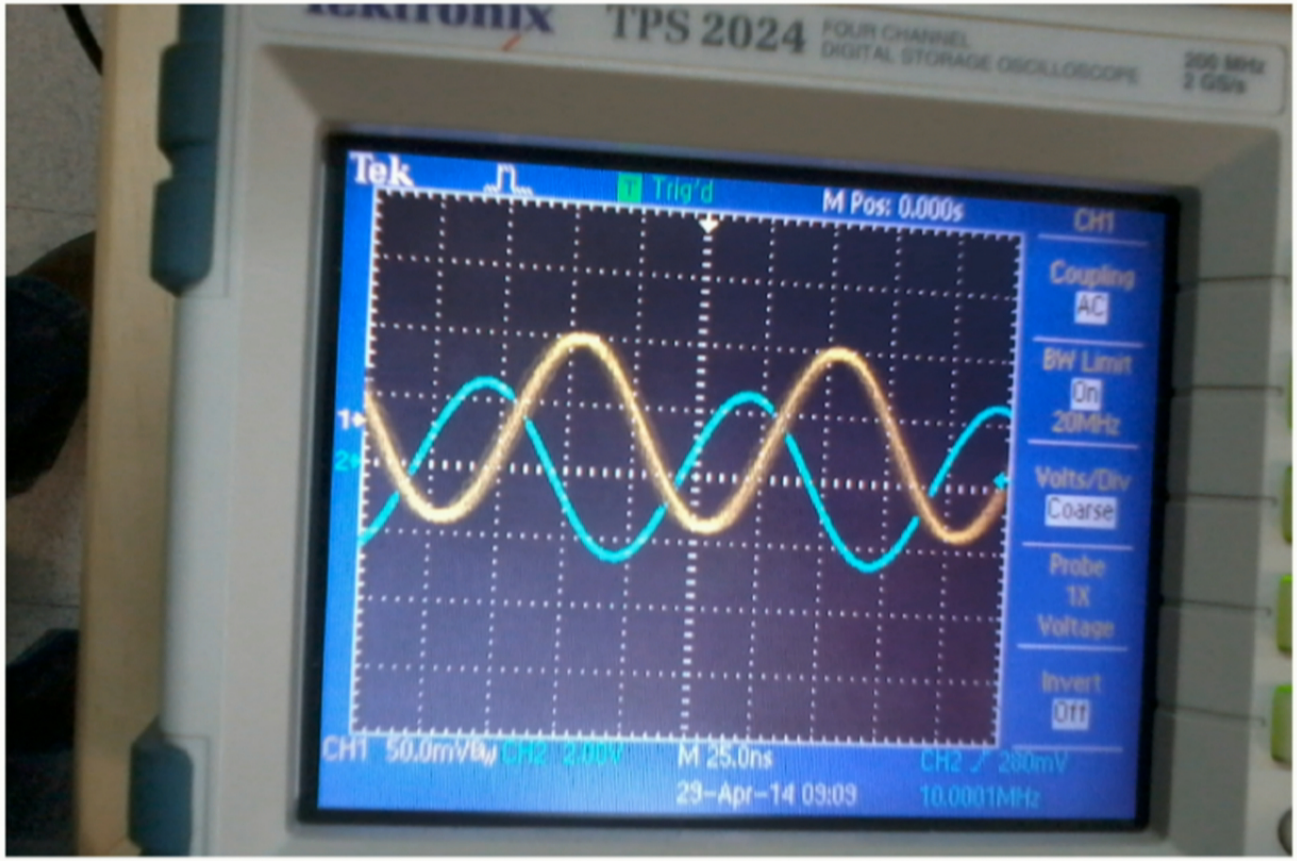
9io9 identified as lensed object by volunteers in Zooniverse Project!

LMT And EHT Readiness

VLBI Preparations at the LMT

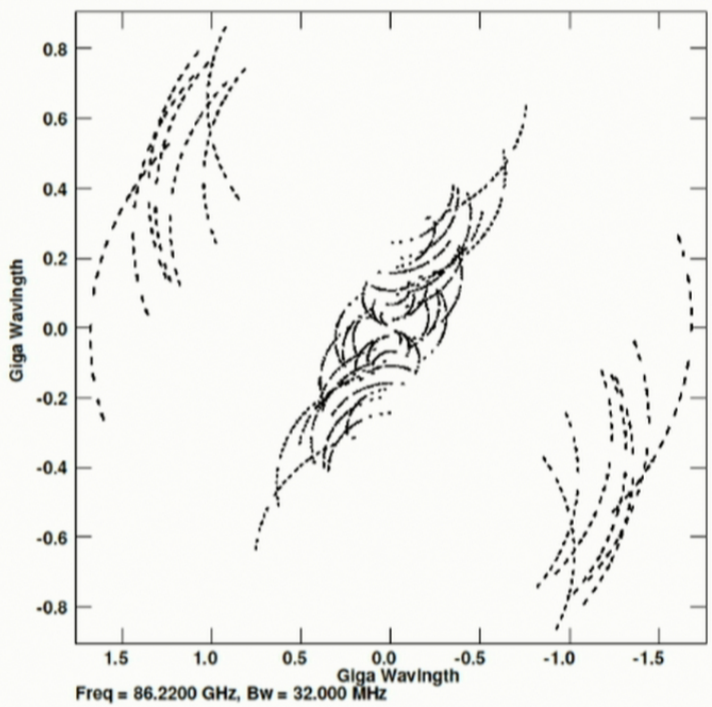


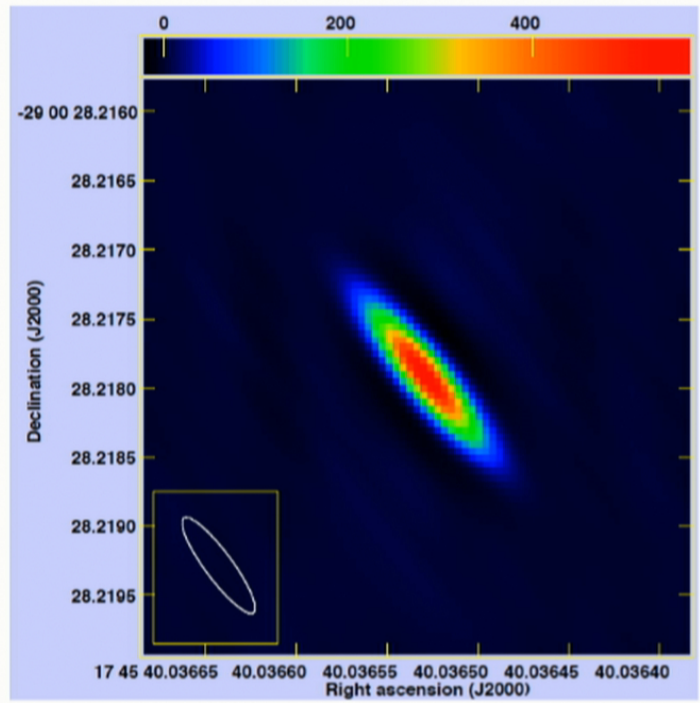
- 2 successful seasons of 3mm VLBI with RSR on the LMT
- Symmetricom Maser installed in Spring 2014
- Haystack downconverter, Roach Digital Backend (RDBE), Mark5C data recorder, GPS hardware all working well
- RCP & LCP of RSR recorded



Blue: Maser; Yellow: 10 MHz from test-tone through entire receiver chain

- Strong Detection of Sgr A* on all baselines involving LMT
- Sgr A* imaging, apparent size is ~160 micro arcsec (see poster by Gisela Ortiz)





EHT 1.3 mm VLBI Receivers for LMT

- Two receivers to be built – one dubbed 'interim' (install in 2015) and the other the facility 'MSIP' receiver (install in 2016)

Interim 1.3 mm Receiver

- Interim 230 GHz receiver primarily meant to enable LMT to participate in EHT VLBI observations for March 2015
- Receiver being assembled at Haystack, mixer/amps provided by CARMA, cryostat/refrigerator provided by UMass, LMT assists in optics and mount
- Dual Polarization Double sideband (DSB) receiver to operate at an LO frequency of 232.1 GHz
- System integration Nov 2014, shipping, installation and commissioning on LMT by Jan 2015; VLBI run March 2015

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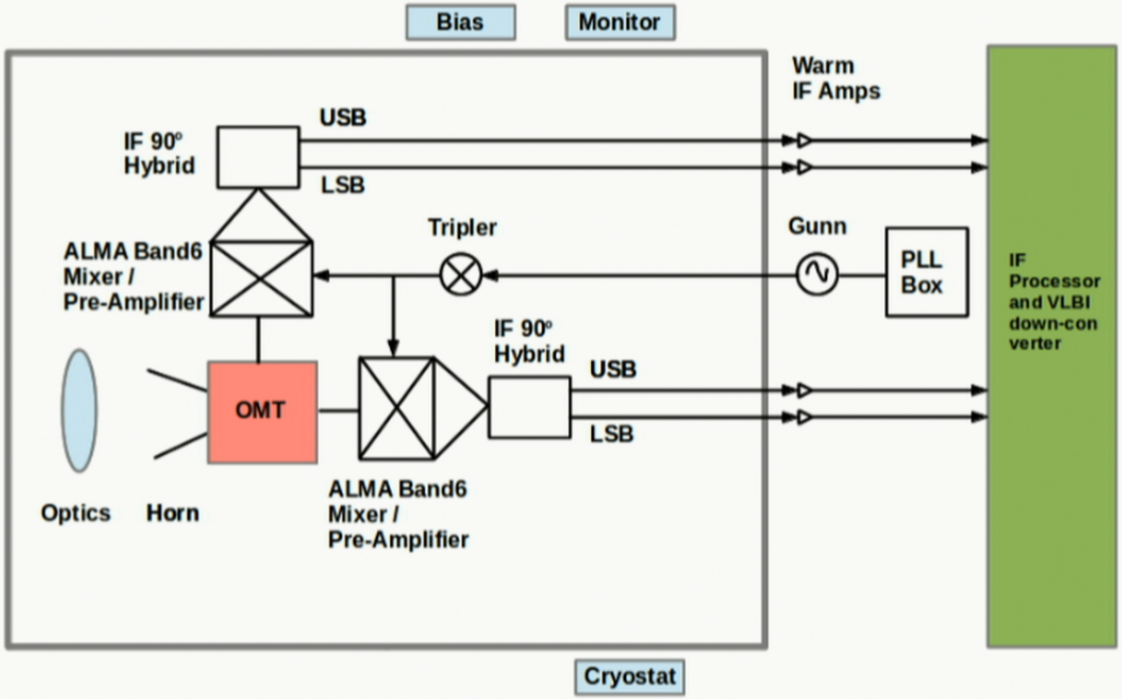
Facility 1.3 mm VLBI Receiver (for Spring 2016)

- Dual polarization sideband-separation receiver (higher sensitivity)
- LO injection via waveguide (better phase stability)
- Broader RF coverage (210 – 280 GHz) and IF bandwidths (4 – 12 GHz)



SUMMARY

- LMT has been commissioned and is collecting valuable scientific data, with the third season of “Early Science” observations ongoing
- A wide variety of scientific projects are being carried out with the Redshift Search Receiver and AzTEC instruments
- Full 50m diameter will be available by 2016, but the current 32.5 diameter LMT is still the largest single dish telescope at 1.3 mm wavelength
- LMT has been provisioned with VLBI equipment including a hydrogen maser, and has had 2 successful 3mm VLBI runs
- With new 1.3 mm wavelength VLBI receivers, LMT is poised to participate in the EHT experiment starting 2015